

This is taken from

Hogg and Tanis: Probability and Statistical Inference, 6th Edition, Prentice Hall

S.7 2000

Centerpiece

Statistical Thinking: The Importance of Understanding Variability

(Hogg's Talk will ramble around some of these thoughts)

This centerpiece is written as a transition as we move from probability to statistical inference. Much of this discussion involves improving situations in a manufacturing context, but clearly it can be applied to the service industries as well. As a matter of fact, really understanding variation, which is the key element of probability and statistics, is extremely important in so many phases of life. Yet as frequently happens in studying a textbook like this, we are so involved in the mathematics of probability, distributions, sampling distributions, and even descriptive statistics that we miss the real meanings of some of these concepts, particularly as far as the role they play in day-to-day activities. Even the definitions and distributions of the t and F random variables say something about understanding variability. Both t and F are defined as the ratio of two independent random variables. The resulting distributions have heavier tails than the respective random variables in the numerators. For example, the t random variable has a standardized normal random variable in the numerator and the p.d.f. of t is much heavier in the tails than that of $N(0, 1)$. That is, there is a tendency to get more outliers in sampling from the t distribution than from $N(0, 1)$. Thus ratios that measure something per something else often exhibit more variability than occurs in the normal distribution, particularly if that quantity in the denominator is a random variable. And we often observe the situation in which the denominator is a variable, creating a ratio that has more variability than we think it should have. For illustration, suppose we observe successive sample averages, say $\bar{x}_1, \bar{x}_2, \dots, \bar{x}_k$. However, the sample sizes change from one sample to the next, say n_1, n_2, \dots, n_k . If these sample sizes vary enough, the \bar{x} -values could look as if they arose from an approximate t -distribution due to the fact that the variance of the averages is changing due to the different sample sizes. That is why in practice we often see more variation in a plot of sample means than we might expect.

In Chapter 1, we did note a few important things about variability. For instance, it explains what is commonly called the "sophomore jinx": some freshmen (rookies) have great first years (above their averages) and then most of them do worse the second year. The same explanation can be applied to movies that have sequels: often the original was outstanding but even with the same cast and same director, the sequel is usually worse than the original.

We had also noted that workers who do very well (above their averages) and who thus might be given some reward, usually do worse during the next work period. On the other hand, those who have bad periods (below average) and are reprimanded frequently do better the next. Yet it is wrong to think that a policy of reprimand is better than that of a pat on the back. Both situations can be explained by understanding the worker's pattern of variation. If the employer really wants to improve the outcome of the process, he or she must consider ways of improving the level (average). The workers can sometimes make small adjustments, but they need road maps to make the major ones. Thus it is really the responsibility of management to improve the process substantially. That is, management must realize that working harder with techniques that have failed will not improve the situation much. Changes must be made, and often data and the resulting statistical analysis can suggest changes for the better.

It is also disturbing to see the following situation: Suppose that the manager has created a team (say of 10) of outstanding workers, and it is time to give raises. The workers are ranked from one to 10. (It is always true that 10 workers, no matter how good or how bad, will always get the ranks 1, 2, 3, . . . , 10.) Then say they get raises according to their ranks, which might have been determined simply by a random process for this particular period. That is, in the next period, their ranks might be entirely different. How does the small raise affect the feelings of the one with lowest rank if, in fact, all 10 are members of an outstanding team, and there might be little or no difference among the persons ranked one and 10? Not good, and he or she is less likely to help the ones with higher ranks in a future period; this does not promote teamwork. As a matter of fact, there is always this danger in any kind of reward, such as the "worker of the month." Others are not likely to help that person the following month, because they want to be the worker of the month and receive the corresponding bonus.

A better way of rewarding a good team would be to give them essentially the same raises. Clearly, a good manager will continuously monitor performance and supply appropriate feedback to the workers. Of course, if one worker is consistently on the high side, then he or she should be considered for promotion or a substantial raise. On the other hand, if some worker is on the low end most of the time, some help for this worker is in order: perhaps additional training or a transfer to a different department for which the worker's talents are more suitable. It is important not to demean this worker because each of us needs to take pride in our accomplishments. If at all possible, firing the worker should be avoided, maybe by finding some other suitable job in the company.

Some teachers will announce to a class of 30 students that there will be only so many As, so many Bs, and so on. This is wrong! If those students are competing for those given number of As, why would anyone want to help anyone else? It completely destroys any sort of teamwork, and yet that is what students must learn to do when they are on the job later in life. Clearly, it is better to say that all of them can earn an A (they probably won't) and encourage them to work together. In that way, the teacher has a better opportunity to improve the level of the entire class which, after all, is the real objective. Too frequently mathematics and science courses discourage interaction among students, and teachers must do everything possible to

break down those barriers.

Many of these preceding observations are those of W. Edwards Deming, an esteemed statistician, who went to Japan after World War II and taught the Japanese how to make quality products. For his work there, he was awarded the Emperor's Medal and the Japanese established the Deming Prize to be awarded each year to the company or individual contributing the most to quality improvement. One of the particulars Deming stressed is the need for "profound knowledge," and a major point is understanding variation and statistical theory.

In making quality products, you want to reduce the variation as much as possible and move the level closer to the target. Deming believed that barriers between departments, between management and workers, and among workers must be broken down to improve communications and the ability to work as a team. The lines of communication, all the way from suppliers to customers, must be open to help reduce variation and improve products and services. For example, he argued that a company should not buy only on price tag but have a few reliable suppliers (possibly one) for a single part because that will reduce variation. That is, many different suppliers would obviously increase variation. Moreover, he argued that you should become partners, friends if you like, with your suppliers: Each learns to trust the other; in that way, you can use methods like "just in time," in which your inventory can be kept reasonably small, to keep costs down.

If each of us thinks about these ideas, we might become obsessed by understanding variation, and that might make a big difference in our everyday lives. For illustration, once we have selected good suppliers, we continue to go to the same barber, the same service station, the same clothier, the same bank, and on and on. We like to buy items, even though a little more expensive, from places that will give us good service if something goes wrong. If this does not happen, then, of course, we must consider changing suppliers.

Clearly, listening to the customer can help improve the quality of our products and services. We can then meet—or even exceed—the expectations of our customers. We should continually try to improve by reducing the variation and moving the process to a better level (high is not always good, as in golf). Although the customer—as well as the supplier—must be part of the total team, more often management must continue to look for better ways to do things, ways that the customer never would have imagined. For example, in the early days of automobiles not many owners would have thought of driving on pneumatic tires. Harvey Firestone did, and in this way exceeded the expectations of those early customers.

Deming also preached constancy of purpose. If management ideas tend to change too much, employees really do not know what to do and cannot do their best. That is, they are mixed up, increasing variation. It is better for them to receive a constant signal from their employer, a signal that changes only if research dictates ways of improving.

More training and education for everyone associated with a company also decreases variation by teaching how to make the product more uniform. Workers must know that they do not have to be afraid to make suggestions to improve the process. Often, being team members will make it easier for workers to speak up without fear of reprisal.

Many of us remember playing a game called “telephone”: one whispers a message to the next person, who whispers the message to the next, and so on. The message at the end is compared to the original message, and it is usually quite different from the original. This is like trying to hit a target (say at zero) with a random variable X_1 . Then starting with X_1 as the center and adding on another error X_2 , and so on, creating the sum of the errors, $X_1 + X_2 + \dots + X_n$, which has an ever-increasing variance with independent errors. Deming would say, “We are off to the Milky Way.” Yet we actually do this in business and industry by letting worker train worker. Once errors are introduced, they will stay there and others will add on and on. (Incidentally, we might say the same thing about too many layers of management.) To decrease variation, wouldn’t it be better to have a master instructor train each worker (or have fewer layers of management)?

Deming also noted that requiring quotas does not help the quality. A foreman who has a quota of 100 per day will often ship out 90 good and 10 bad items just to make the quota. Clearly, it would reduce the variation and satisfy the customer better if only the 90 good ones were shipped.

This leads to the point that a final inspection of products often does not really improve the quality. With such a procedure, you can only eliminate the bad ones and send on the good ones. Improvements in the design of the products and manufacturing processes are needed. If these are done well, often with the help of statistical methods, that final inspection can be eliminated. That is, improvements should be made early in the manufacturing process rather than trying to correct things at the end inspection by weeding out the bad items.

Once you recognize that there is variation in almost every process, you begin to think like a statistician. Often you want to reduce that variation and center the remaining variation at the right level, because as a result “the doors will fit better.” But while we want to reduce undesirable variation, we do not want to reduce all variation: Most of us do not want to eat Chinese food every night even though we enjoy it from time to time. Certain variation is “the spice of life.”

This desire to understand variation is the key to statistical thinking. As a matter of fact, in the quality improvement area, Ron Snee, another quality guru, defines statistical thinking as “thought processes, which recognize that variation is all around us and present in everything we do, all work is a series of interconnected processes, and identifying, characterizing, quantifying, controlling, and reducing variation provide opportunities for improvement.”

In a sense, statistical thinking can affect everything we do, including our relationships with others. All of us have our “ups and downs,” and we must seriously think about how to deal with others, recognizing this variation.

It is the authors’ opinion that this quality improvement must begin with the individual by creating a personal vision, goals, and principles by which to live. Hopefully, one of those individuals is the chief of the organization for then things go much smoother. Bob Galvin, who was the CEO of Motorola during the 1980s, believes that “quality improvement is a daily, personal, priority obligation,” and his company made great improvements in the quality of their products during that period. Much of this progress was due to understanding variation and statistical methods. Even

Motorola's program was called Six-Sigma in which sigma referred to a standard deviation: a name which is a delight to a statistician. But the description of that program is another story for another day.

Each of us should use as much statistical thinking as we are capable of to help us build trust with the persons with whom we deal directly or indirectly. Let us not do what those administrators of that university did when they did not understand the variability associated with ranking people. That action destroyed any trust that was there and created a mean competition among the members of that faculty. Why should anyone help others when his or her gain only hurts an individual? While statistical thinking cannot solve all problems, it most certainly can help in many situations. We hope you use what statistics of which you are knowledgeable to benefit you the rest of your life.